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Grain and Forage Sorghum Production with No-Tillage on Dryland

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ABSTRACT

Grain sorghum [*Sorghum bicolor* (L.) Moench] is adapted to the Southern and Central Great Plains, but water stress at critical reproductive stages can sharply reduce grain yields of the crop on dryland. In contrast, forage sorghums (*S. bicolor sudanense* or *saccharatum*) have no such critical stages and, hence, do not require such timely rainfall to attain good yields. This study compared growth, production, water use, and water-use efficiency of grain and forage sorghums under no-tillage conditions on dryland from 1984 to 1986. All cultivars attained similar heights at 30 d after planting, but forage sorghums were taller at later times. Average total dry matter (TDM) production by grain and forage sorghums (8.14 vs. 8.61 Mg ha^{-1}) was not significantly different. Total (grain plus stover) crude protein production was higher for grain than for all forage sorghums except 'Sugar Dan'. Total digestible energy (DE) and metabolizable energy (ME) production also were higher for grain sorghum. Grain sorghum stover, however, has low nutrient value and usually is not harvested. When only grain of grain sorghum is considered, nutrient production (crude protein, DE, and ME) was lower than that for forage sorghums. Water-use efficiency for TDM and nutrient production was lower for grain than for forage sorghums because grain sorghum had a longer growing season, which resulted in higher growing season precipitation and total water use than that for forage sorghums. In conclusion, forage sorghums are viable alternative crops to grain sorghum on dryland in the Southern Great Plains where forages can be used by the cattle (*Bos* spp.) industry.

***Additional Index Words:* *Sorghum bicolor* (L.) Moench, *Sorghum bicolor sudanense*, *Sorghum bicolor saccharatum*, Crude protein, Soil water content, Water use, Water-use efficiency.**

GRAINS and forages are important feeds for livestock, with grain and forage sorghums being important feed crops for the extensive cattle industry of the Central and Southern Great Plains. Depending on the cultivar, the sorghum may be grazed or harvested for grain, hay, or silage.

Grain sorghum is adapted to the semiarid Southern and Central Great Plains. Although it responds to irrigation (Musick and Dusek, 1971), it also performs well on dryland, especially when soil water is not limiting at planting, and rainfall is near normal during the growing season (Unger, 1984; Unger and Wiese, 1979). Sorghum grain yields on dryland, however, can be reduced sharply by water stress during critical reproductive growth stages (booting, flowering, grain filling), even though early growth may provide for near-normal stover production (Unger and Wiese, 1979). When collected at or after grain harvest, the stover of grain sorghum has relatively low food value for cattle (National Research Council, 1982). Consequently, it was hypothesized that forage sorghums, which also respond to increased amounts of water but which do not have the critical growth stages of grain sorghum, could use water more efficiently than grain sorghum for production of marketable or usable dry matter. The objectives of this study were to compare growth, dry matter and nutrient production, water use, and water-use efficiency of grain and forage sorghums grown on dryland under no-tillage conditions.

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METHODS AND MATERIALS

The study was conducted from 1984 to 1986 at the USDA Conservation and Production Research Laboratory, Bushland, TX. The soil type at the study site was a Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll) with less than 1% slope. The sorghums followed winter wheat (*Triticum aestivum* L.) in a two-crop, 3-yr rotation of wheat-fallow-sorghum-fallow on no-tillage field areas. Areas used in 1984, 1985, and 1986 were last tilled in 1979, 1983, and 1982, respectively.

Wheat on the respective areas was harvested in June 1983, 1984, and 1985. Soon after wheat harvest, atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine][1] and 2,4-D [2,4-dichlorophenoxy) acetic acid] were applied at rates of 0.34 and 0.11 g m^{-2}, respectively. During the 1984 to 1985 and 1985 to 1986 fallow periods, one application of glyphosate [*N*-(phosphonomethyl) glycine] at 0.11 g m^{-2} was used for additional weed control. Also, terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-*s*-triazine] at 0.22 g m^{-2} was applied before planting sorghum each year for growing-season weed control.

One grain and five forage sorghums were planted on separate but adjacent areas each year. Separate areas were used to minimize microenvironmental effects due to plant height differences between the grain and forage sorghums. The forage sorghum plantings were replicated four times in a randomized complete-block design experiment. Plots were 9.0 m (twelve 0.75-m rows) wide and 15 m long. The grain sorghum was in an adjacent planting rate study that also had a randomized complete-block design and was replicated three times. Plot size was the same as that for forage sorghums.

Soil water contents at or near planting and after harvest were determined gravimetrically on core samples obtained by 0.30-m increments to a 1.2-m depth at one site per plot. The soil retains 236 mm of water at a −1.5-MPa matric potential. Above −1.5 MPa, the soil can retain about 170 mm of plant available water to a 1.2-m depth (Unger and Pringle, 1981). Precipitation was measured about 0.5 km from the plot area.

Planting dates were 6 June 1984, 30 May 1985, and 16 June 1986. The grain sorghum was DeKalb 'DK-46', a medium-maturity hybrid. A medium-maturity hybrid was used because hybrids of this maturity class are better adapted to dryland in this region than early or late-maturity hybrids (J. T. Musick, 1983, personal communication). Early maturity hybrids have lower yield potentials. Late-maturity hybrids are not well-adapted because of the limited water supply under dryland conditions. Hybrid DK-46 was used because it is well-adapted and has yielded well in other studies, but generally is not greatly different from other adapted hybrids. The forage sorghums were 'Pioneer 911'; 'Bale All II 6204', 'Sugar Dan 6196', and 'Sile-All 4714' (Garrison Seed Co.,[1]

[1]This paper reports the results of research only. Mention of a pesticide, trade name, or product in this paper does not constitute a recommendation or endorsement for use by the U.S. Department of Agriculture, nor does it imply registration under FIFRA as amended.

Table 1. Yields and nutrient values for grain and forage sorghums, Bushland, TX, 1984-1986.

Yield or nutrient factor	Grain sorghum			Forage sorghum					
	Grain	Stover	Total	Pioneer	Bale All	Sugar Dan	Sile-All	Goldmaster	Average
Yield, Mg ha^{-1}									
1984	5.12	5.12	10.25	10.09	12.96	11.24	12.06	9.84	11.24
1985	2.82	1.88	4.70	5.46	5.66	5.96	6.01	6.18	5.85
1986	5.72	3.59	9.31	9.45	8.46	8.22	9.19	8.40	8.74
Avg.	4.55	3.53	8.08	8.33	9.03	8.47	9.09	8.14	8.61
	Protected LSD, 5%: forage sorghum (avg.) for years = 0.46 Mg ha^{-1}; grain sorghum (total) for years = 1.32 Mg ha^{-1}								
Crude protein†									
%	12.4	5.2	8.8	6.2	6.2	10.8	6.2	6.2	7.1
Mg ha^{-1}	0.56	0.19	0.75	0.52	0.56	0.91	0.56	0.50	0.61
Digestible energy†									
Mcal kg^{-1}	3.79	2.38	3.09	2.56	2.56	2.43	2.56	2.56	2.53
Mcal ha^{-1} (× 10^{-3})	17.2	8.5	25.7	21.3	23.1	20.6	23.2	20.8	21.8
Metabolizable energy†									
Mcal kg^{-1}	3.38	1.96	2.67	2.13	2.13	2.00	2.13	2.13	2.10
Mcal ha^{-1} (× 10^{-3})	15.4	7.0	22.4	17.7	19.2	16.9	19.4	17.3	18.1

† Based on values reported by the National Research Council (1982).

Hereford, TX); and 'T. E. Goldmaster' (Taylor Evans Seed Co.,[1] Tulia, TX). Planting rates were 3.4 and 5.6 kg ha^{-1} for the grain and forage sorghums, respectively, resulting in about 96 000 and 185 000 plants per hectare for the grain and forage sorghums, respectively. Differences in populations among forage cultivars were relatively small. Use of a higher planting rate for forage sorghums is a common practice. However, yields of the grain sorghum were not significantly different when planted at rates of 1.7, 3.4, or 5.1 kg ha^{-1} (author's unpublished data). Planting was accomplished with John Deere Max-Emerge 7100[1] double-disk opener units (John Deere Co., Moline, IL) preceded by a straight coulter. Planting direction was east and west, and perpendicular to the drill rows of the previous wheat crop.

Plant heights were monitored during the growing season. Forage sorghum yields were determined from 3-m sections of two rows at two sites per plot by hand harvesting (at ground level), weighing, and subsampling to determine dry matter content. The forage sorghums were harvested when the grain of grain-producing cultivars was at the soft-dough stage. Pioneer, which does not produce grain, was harvested at the same time. Harvest dates for forage sorghum were 10, 4, and 9 September in 1984, 1985, and 1986, respectively. Grain sorghum was harvested as soon as practical after frost that occurred on 29 Sept. 1984, 29 Sept. 1985, and 12 Oct. 1986. Grain and stover yields were determined by hand-harvesting samples from the same-size areas as those for the forage sorghums. All grain and forage sorghum samples were oven-dried at 60°C, and the results are reported on that basis. Published values (National Research Council, 1982), included in Table 1, were used to calculate crude protein, digestible energy (DE), and metabolizable energy (ME) content of the plant materials.

An analysis of variance involving the grain sorghum and forage sorghums in a combined analysis was not justified because of the experimental layout. However, the analysis of variance technique was used to determine significant differences among forage sorghum cultivars and among years for the grain sorghum. When the F test showed statistical significance, the Protected LSD (Steel and Torrie, 1982) was calculated. Also, a t test (SAS Institute, 1985) was used to determine the statistical significance of differences between mean values for the grain and forage sorghums. For the t test, there were 8 and 11 degrees of freedom for the grain and forage sorghums, respectively.

Table 2. Precipitation during grain and forage sorghum growing seasons at Bushland, TX, 1984-1986.†

Year and growing season	Month					Total precipitation
	June	July	Aug.	Sept.	Oct.	
	mm					
1984						
Grain sorghum	129	37	89	20	--	275
Forage sorghum	129	37	89	10	--	265
Total for month	130	37	89	20	67	343
1985						
Grain sorghum	54	47	44	121	--	266
Forage sorghum	54	47	44	0	--	145
Total for month	54	47	44	167	67	379
1986						
Grain sorghum	27	29	103	49	58	266
Forage sorghum	27	29	103	17	--	176
Total for month	133	29	103	49	69	383
Average						
Grian sorghum	70	38	79	63	19	269
Forage sorghum	70	38	79	9	--	195
Total for month	106	38	79	79	68	370
47-yr avg.	74	65	70	46	43	298

† Total precipitation for June, September, and October may be different from growing season precipitation for these months because some of the precipitation may have occurred before planting or after harvest.

RESULTS AND DISCUSSION

Growing-Season Precipitation

Precipitation (rainfall) amounts from planting to harvest and long-term average amounts for the periods are given in Table 2. June rainfall was much above average in 1984 and 1986, with that in 1984 occurring after planting. July rainfall was low each year. August rainfall was above average in 1984 and 1986, but the average for the study was near the long-term average. September rainfall was low until forage sorghum harvest, but the total for the month was above average in 1985 and near average in 1986. September rainfall had little effect on forage sorghums, but may have increased grain sorghum yields because this sorghum was not harvested until after frost in late September (1984 and 1985) or October (1986). Except in 1986, all October rainfall occurred after grain sorghum had been killed by frost. Although the average total for October was above the long-term average, the average amount that occurred before frost was below the long-term average for that month. Because of the later harvest, growing-season rainfall av-

Table 3. Soil water contents and soil water use by grain and forage sorghums at Bushland, TX, 1984-1986.

Sampling time and year	Grain sorghum	Forage sorghum					
		Pioneer	Bale All	Sugar Dan	Sile-All	Goldmaster	Average
	mm						
At planting							
1984	108	101	113	101	105	106	105
1985	150	152	138	144	134	136	141
1986	151	150	141	147	149	142	146
Average	136	134	131	131	129	128	131
	Protected LSD, 5%: forage sorghums (avg.) for years = 10 mm; grain sorghum for years = 13 mm.						
At harvest							
1984	32	30	28	24	30	26	28
1985	36	19	26	48	36	26	31
1986	31	20	32	20	16	33	24
Average	33	23	29	31	27	28	28
	Protected LSD, 5%: forage sorghum for cultivar × year = 13 mm. The t-test (5%) for grain vs. forage sorghum comparison is significant (t = 6.98).						
Soil water use							
1984	76	71	85	77	75	80	79
1985	114	133	112	96	98	110	110
1986	120	130	109	127	133	109	122
Average	103	111	103	100	102	100	103
	Protected LSD, 5%: forage sorghum (avg.) for years = 19 mm, for cultivar × years = 18 mm; grain sorghum for years = 17 mm.						

eraged 74 mm greater for grain than for forage sorghums.

Soil Water Contents and Water Use

Uniform no-tillage management during fallow periods resulted in nonsignificant differences among soil water contents at planting time in plots used for the grain and forage sorghums (Table 3). There were, however, significant differences among years, with the lowest water contents at planting occurring in 1984 because of low precipitation (202 mm) during the July 1983 through May 1984 fallow period. The long-term average is about 400 mm for this period at Bushland. During the 1984 to 1985 and 1985 to 1986 fallow periods, precipitation totaled 418 and 410 mm, respectively, and soil water contents at planting in 1985 and 1986 were similar and near *field capacity* for the Pullman soil to the 1.2-m depth.

There were no statistically significant differences in soil water contents at harvest due to forage cultivars or years, but the cultivar × year interaction was significant. This significant interaction resulted from generally higher soil water contents for the Sugar Dan and Sile-All cultivars than for other cultivars in 1985, and generally lower soil water contents than for some other cultivars in 1986. The reason for these differences is not apparent. Average soil water content at harvest was significantly higher ($P = 0.05$) for the grain than for the forage sorghums, and was attributed to rainfall that occurred during the period (26-d average length) from forage sorghum harvest to frost-kill of grain sorghum. This rainfall partially replenished the soil water supply, but all the water was not used by the grain sorghum before it was killed by frost.

Net soil water use (difference in contents at planting and harvest) was not significantly different among forage sorghums. Also, the average water use difference between grain and forage sorghums was not statistically significant. However, soil water use was significantly lower in 1984 than in 1985 and 1986. The forage sorghum cultivar × year interaction was significant also. Lower soil water use in 1984 resulted from the lower water contents at planting in that year. The significant interaction effect resulted from less soil water use by Sugar Dan and Sile-All than by Pioneer in 1985, and more water use than by Bale All and Goldmaster in 1986. The reason for these soil water use differences is not apparent.

Total water use (net soil water use plus rainfall) by forage sorghums was highest in 1984, followed in decreasing order by that in 1986 and 1985. In each year, total water use by grain sorghum exceeded that by forage sorghums, with the average increase being 27%. The increase resulted from rainfall (74-mm average) that occurred during the 26-d average period from harvest of forage sorghum to harvest of grain sorghum.

Plant Heights, Grain and Forage Yields, and Nutrient Values

For forage sorghums, plant height differences due to cultivars, days after planting (DAP), years, and all interactions were significant at $P = 0.001$. Average differences between the grain and forage sorghums at 60 and 90 DAP were significant at $P = 0.05$.

At 30 DAP, heights were similar (18-cm average) for the grain and forage sorghums in 1984 and 1985. In 1986, plants of both sorghum types were taller (32-cm average) at 30 DAP than in previous years. More rapid growth in 1986 is attributed to the later planting date, which possibly resulted in more favorable soil temperatures for plant growth.

At 60 DAP, Sugar Dan was as tall or taller (141-cm average) than other sorghums each year. Sugar Dan was tallest at 90 DAP in 1984 (210 cm) and 1985 (167 cm); Pioneer was tallest (223 cm) in 1986. Overall, Sugar Dan averaged tallest (196 cm) and Goldmaster averaged shortest (163 cm) at 90 DAP. The average final height for grain sorghum was 105 cm. Although forage plants neared or exceeded 2 m in height at the final measurement (near harvest), no lodging or harvesting problems due to plant height were encountered.

Table 4. Average water-use efficiency by grain and forage sorghums, Bushland, TX, 1984–1986.

Water use factor	Grain sorghum			Forage sorghum					
	Grain	Stover	Total	Pioneer	Bale All	Sugar Dan	Sile-All	Goldmaster	Average
Yield, kg m^{-3}	1.22	0.97	2.19	2.72	3.04	2.87	3.06	2.76	2.89
Crude protein, kg m^{-3}	0.15	0.05	0.20	0.17	0.19	0.31	0.19	0.17	0.21
Digestible energy, Mcal m^{-3}	4.62	2.28	6.90	6.96	7.78	6.98	7.90	7.05	7.33
Metabolizable energy, Mcal m^{-3}	4.14	1.88	6.02	5.78	6.46	5.73	6.53	5.86	6.07

Total dry matter (TDM) yields for grain and forage sorghums were highest in 1984 and lowest in 1985 (Table 1). In 1984, growing-season rainfall was higher than in other years. In 1985, rainfall during the forage growing season was lowest. The overall average TDM yield favored forage sorghums by 0.47 Mg ha^{-1}, but the difference was not statistically significant. Also, yield differences among forage sorghums were not statistically significant.

Because of higher crude protein percentage of grain than of forage (Table 1), crude protein yield of grain sorghum grain equaled or exceeded that of all forage sorghums except Sugar Dan, a sudan-type sorghum (*S. bicolor sudanense*). The other forage sorghums are sorgo types (*S. bicolor saccharatum*). Because stover of grain sorghum often is not harvested, crude protein production by grain sorghum was lower than that for Sugar Dan and about equal to that for the other forage sorghums.

The total DE and ME production was highest for grain sorghum (grain plus stover), but this production was approached by that for Bale All and Sile-All. Again, if stover of grain sorghum is not considered, then DE and ME production by forage sorghums exceeded that of grain sorghum.

Water-Use Efficiency

Water conservation and efficient use of available water resources are important aspects of crop production in semiarid regions. Under dryland conditions, water used by crops is that extracted from the soil plus that provided by precipitation during the growing season. To evaluate differences between the grain and forage sorghums or among forage sorghums themselves, water-use efficiencies (WUEs) based on total water use and yield, crude protein, DE, and ME production were determined (Table 4).

As discussed in the previous section, total yield, protein, DE, and ME production by grain sorghum approached or exceeded the production by forage sorghums in most instances. However, the WUEs for all forage sorghums were higher than the total (grain plus stover) for grain sorghum for all factors except for crude protein and ME. For crude protein, the WUEs were similar except for Sugar Dan, which had the highest WUE. The WUE for ME production by grain sorghum (grain plus stover) was higher than that for Pioneer, Sugar Dan, and Goldmaster. Average WUEs for yield, crude protein, DE, and ME for forage sorghums exceeded the total for these factors for grain sorghum by 32, 5, 6, and 1%, respectively. When considering only the grain of grain sorghum, the averge increases were 137, 40, 59, and 47%, respectively.

The average grain yield of 4.55 Mg ha^{-1} in this study was well above the average of 3.23 Mg ha^{-1} for no-tillage dryland grain sorghum in previous studies at this laboratory (Unger, 1984; Unger and Wiese, 1979). This suggests that the forage sorghum yields also were higher than those that would be obtained over a longer time period. In the previous studies (1974 to 1977 and 1979 to 1981), sorghum grain yields with no-tillage were below 2.0 Mg ha^{-1} in 1975 and 1980. Even lower yields occurred with other treatments. Although no grain sorghum crop failures occurred in the previous studies or in this study, grain yields were reduced by water deficits during the growing season. Stover yields also were reduced, but generally to a lesser extent than grain yields. This supports the hypothesis that sorghum has less critical growth stages for stover (forage) production than for grain production and that forage sorghums use water more efficiently than grain sorghum for the production of marketable or usable dry matter.

SUMMARY AND CONCLUSIONS

One grain and five forage sorghum cultivars were grown under no-tillage conditions on dryland to determine growth, yields, nutrient production, water use, and water-use efficiency. Plant heights for both sorghum types were similar near 30 DAP, but forage sorghums were taller at later times.

Average TDM yield for forage sorghums was not significantly greater than that for grain sorghum. Because of higher nutrient values for grain, the grain sorghum (total for grain and stover) produced more crude protein, DE, and ME than the forage sorghums in most cases. An exception was the high crude protein production by Sugar Dan.

The nutrient value of grain sorghum stover is low, and the stover usually is not harvested. When only the grain of grain sorghum was considered, crude protein production by grain and most forage sorghums was similar. It was higher for Sugar Dan. The forage sorghums produced more DE and ME than the grain of grain sorghum. Hence, from the standpoint of crude protein, DE, and ME production, forage sorghums were as valuable as the grain of grain sorghum.

From a total water use and water-use efficiency (WUE) consideration, forage sorghums used less total water and used the water more efficiently for yield, crude protein, DE, and ME production than the grain sorghum. This resulted, in part, from the shorter growing season for forage sorghums than for grain sorghum.

Based on the overall results, it is concluded that forage sorghums are viable alternative crops to grain sorghum on dryland. The forage sorghums use water effectively and are not dependent on adequate water at critical reproductive growth stages as is grain sorghum for grain production. Hence, forage sorghums may be a desirable crop on dryland where suitable outlets for forage are available (for example, the cattle feeding industry).

One major disadvantage of growing forage sorghums is that most aboveground plant material is harvested. This leaves the soil surface devoid of protective residues and could result in soil erosion problems. Where the potential for soil erosion exists, tillage may be needed to provide protection against erosion. Other potential disadvantages of growing forage sorghums are more rapid depletion of soil organic matter and greater fertilizer requirements because less residues are returned to the soil.

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